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# Highly indistinguishable photons from a QD-microcavity with a large Purcell-factor

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**Abstract:** We demonstrate the emission of highly indistinguishable photons from a quasi-resonantly pumped coupled quantum dot–microcavity system operating in the weak coupling regime. Furthermore we model the degree of indistinguishability with our novel microscopic theory.



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## 1. Introduction

Single indistinguishable photons are key to applications in the field of quantum communication [1], quantum networks [2], linear optical quantum computing [3] and quantum teleportation [4]. One of the most promising platforms for single photon sources are solid-state quantum dots (QDs) [5]. When embedded in a bulk semiconductor, however, QDs suffer from poor photon extraction efficiencies since only a minor fraction of the photons can leave the high refractive index material. This problem can be mitigated by integrating QDs into optical microcavities [8] , which can enhance extraction efficiencies to values beyond 50%.

## 2. Experiment

In this work, we exploit a microcavity with a high Purcell factor and weak non-resonant contributions of spectator QDs to probe the interference properties of photons emitted from a single QD as a function of the QD-cavity detuning. The QD is placed in an adiabatic micropillar [9] with a diameter of $d = 1050$ nm and a quality factor of $Q = 3200$. Via temperature tuning, we can sweep the QD-emission through the fundamental optical mode of the pillar. For spectral resonance between QD and cavity, we observe a pronounced enhancement of the emission. Via time-resolved measurements, we are able to measure the lifetime of the QD-excition for different detunings which yields a Purcell enhancement of $F_P = (7.8 \pm 2.3)$.
The QD was excited quasi-resonantly with a pulsed Ti:Sapphire Laser (repetition rate 82 MHz) assisted by a longitudinal optical phonon transition. Due to this excitation scheme, we were able to measure pure single photon emission with $g^{(2)}(0)$-values as low as $g^{(2)}(0) = (0.036 \pm 0.005)$.
Via a fiber-coupled unbalanced Mach-Zehnder-interferometer (MZI) we carried out two-photon-interference (TPI) measurements. Fig 1(a) shows the measured two-photon probability versus the time delay between both arms of the MZI resulting in the Hong-Ou-Mandel-dip with a maximal TPI-visibility of $\nu = (83 \pm 5)\%$.

Furthermore we studied the influence of the QD-cavity detuning on the degree of indistinguishability of the emitted photons (see Fig 1 (b)). In contrast to previous studies, where non-resonant coupling to spectator QDs [10] or strong temperature induced dephasing [11] dominated the experiments, we observe a strong improvement of the TPI-visibility on resonance, which exceeds a factor of 3 compared to the off-resonant case. We extend the theoretical model of Ref. [12] to derive an expression for the Hong–Ou–Mandel dip including the effects of both time-jitter and pure-dephasing on- and off-resonance. This allows us to reject timing-jitter, and attribute sources of pure-dephasing as the dominant factor limiting the indistinguishability of our photons. Furthermore, we show that the degree of symmetry

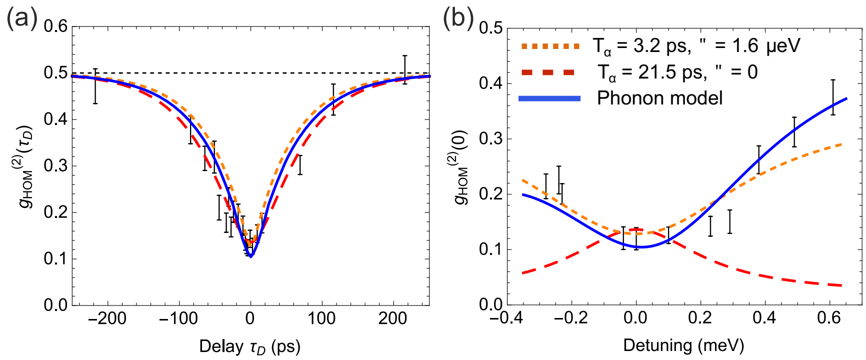


Fig. 1. (a) Two-photon-interference versus the time delay between both arms of the Mach-Zehnder-interferometer. (b) TPI-minimum versus the QD-cavity-detuning. Both curves are fitted by a microscopic model.

we observe for positive and negative detuning suggests pure-dephasing caused by both phonon coupling and spectral diffusion.

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